Semi-Annual Report:

Analysis of Solar Spectral Irradiance Measurements from the SBUV/2-Series and the SSBUV Instruments

Period of Performance: 1 September 1995 to 29 February 1996

25 March 1996

Contract Number: NASW-4864

Principal Investigator: Richard P. Cebula

Co-Investigators: Matthew T. DeLand
Ernest Hilsenrath

1. SUMMARY OF ACTIVITY DURING THE CURRENT PERFORMANCE PERIOD

1.1 Development of the Long-term NOAA-11 SBUV/2 Solar Irradiance Data Set

This Semi-Annual Report for NASA Research Grant *NASW-4864* is an update to the *Interim Report: Analysis of Solar Spectral Irradiance Measurements from the SBUV/2-Series and the SSBUV Instruments*, dated 13 February 1996. The primary purpose of this research is to develop a NOAA-11 SBUV/2 solar spectral irradiance data set which is free from long-term instrument drift, then perform scientific analysis using the data set. During this period of performance, from 1 September 1995 through 29 February 1996, we have transferred the analysis software and data from an IBM mainframe computer to a UNIX workstation, have been updating the NOAA-11 SBUV/2 characterization, and have further refined the SSBUV calibration, each step which must be completed before the long-term calibration of the SBUV/2 solar spectral irradiance data set can be completed.

As a check on software and analysis procedures, a preliminary NOAA-11 Mg II index was developed for the period February 1989 through the end of the data record, October 1994. The index, shown in Figure 1, is considered preliminary because a preliminary instrument calibration was used. The Mg II proxy index shows a 5-6% decrease in the mean level of middle ultraviolet solar activity from early 1992 through late 1994, corresponding to the declining phase of solar cycle 22. The gaps in 1993 and 1994 are the result of the near-terminator spacecraft orbit during this period. A NOAA-9 SBUV/2 Mg II proxy index, constructed using a preliminary calibration of that instrument and normalized to the NOAA-11 index, was used to fill these gaps and extend the data record into early 1995. The result of this procedure is shown in Figure 2. Solar activity remained low during this period.

1.2 Comparisons With Other Instruments

A second major aspect of this work is to compare solar spectral irradiances from the NOAA SBUV/2 instruments and SSBUV with corresponding data from other instruments. Significant activity in this area occurred during the past six months. First, SSBUV data from the ATLAS-1 (March 1992) and ATLAS-2 (April 1993) missions were compared to data from the UARS SOLSTICE and SUSIM instruments. These comparisons are presented in an "in press" Journal of Geophysical Research paper by Woods et al. (1996). Second, SSBUV ATLAS-1 data were compared to SOLSPEC and SUSIM ATLAS-1 data. An average ATLAS-1 solar spectrum was developed and compared to the average UARS solar spectrum for the ATLAS-1 time period. This work is presented in an "in press" Geophysical Research Letters paper (Cebula et al., 1996).

1.3 NOAA-14 SBUV/2 Analysis

The fourth instrument in the SBUV/2 series was launched on the NOAA-14 satellite on 30 December 1994 and first observed the sun on 10 February 1995. The Activation and Evaluation Phase was completed in August 1995 and the Operational Phase of the mission began in September 1995.

Unfortunately, due to significant grating drive problems, daily sweep mode solar spectral irradiance measurements were terminated as of 7 October 1995. Discrete mode measurements at the Mg II index wavelengths commenced in late January 1996. Initial analysis show that these data are also severely impacted by the grating drive problems and that most of the Mg II data acquired at the standard Mg II wavelengths will not be useful in assessing solar rotational and long-term variations. We are continuing to work with NASA and NOAA scientists to develop alternate operations plans, given the ongoing NOAA-14 SBUV/2 grating drive problems. The operational Mg II wavelengths were modified beginning on 20 March 1996 in an attempt to lessen the impact of the grating drive problems.

A *White Paper* explaining the rationale for SBUV/2 solar irradiance measurements and providing a recommended instrument operations schedule was written and delivered to NOAA and NASA personnel. A copy of the *White Paper* is enclosed with this report.

1.4 GOME Analysis

The GOME instrument was launched by the European Space Agency in early 1995 and began making solar irradiance measurements in May 1995. Working with GOME scientists, we are using SSBUV data to validate the GOME solar irradiance data. These comparisons have revealed a significant (on the order of 10 percent or more) spectral bias in the GOME data. We have obtained nineteen days of GOME solar irradiance data and have developed a preliminary GOME Mg II index that is comparable to the SBUV/2 Mg II index. The GOME Mg II index was compared to the preliminary Mg II index from the UARS SUSIM instrument and also to the ground-based F10.7 cm index proxy index. These comparisons, shown in Figure 3, suggest that the GOME Mg II index is tracking short-term solar variations but that medium-term (timescale on the order of a few months) instrument artifacts are biasing the data at present.

1.5 SSBUV Flight

The SSBUV experiment flew for the eighth and final time on STS-72 from 11-20 January 1996. The instrument observed the sun on four separate occasions during the mission. The SSBUV-8 solar irradiance data were analyzed in near real-time during the mission using a preliminary prelaunch calibration. We are presently updating the prelaunch calibration, preforming the postlaunch calibration, and assessing in-flight calibration data. Initial analysis of the SSBUV-8 solar data indicates that instrument once again performed very well. The SSBUV-8 data suggest near and middle UV solar spectral irradiance activity levels comparable with those that existed during the SSBUV-7 mission in November 1994. The preliminary SSBUV-8 solar irradiance data were made available on the World Wide Web (at http://ssbuv.gsfc.nasa.gov) within 24 hours after the first solar observation period.

1.6 SOLERS22 Activities

Dr. Cebula is Leader of the Middle Ultraviolet Working Group (WG2) of the Solar Electromagnetic Radiation Study for Solar Cycle 22 (SOLERS22). SOLERS22 will hold a workshop from 17-21

June 1996 at the Sacramento Peak Observatory. The SOLERS22 1996 Workshop has been "up-graded" to the 17th National Solar Observatory/Sacramento Peak Summer Workshop. As a member of the scientific organizing committee for the Workshop Dr. Cebula has been working with the SOLERS22 Leader, Dr. Judit Pap, to arrange the Workshop, develop an agenda and invite speakers, and coordinate activities related to WG2.

1.7 Presentations and Publications

Three papers discussing research that was supported by NASA Research Grant NASW-4864 were submitted for publication in American Geophysical Union journals during the past six months. Each of the papers have been accepted for publication and all are currently "in press". In addition, two papers were submitted for presentation at the XVIII Quadrennial Ozone Symposium in September 1996. Preprints of the three papers and the Ozone Symposium abstracts are enclosed. Reprints of the three journal papers will be furnished as soon as they are available.

Cebula, R. P., M. T. DeLand, and E. Hilsenrath, *White Paper on SBUV/2 Solar Irradiance Measurements*, Tech. Rep. HSTX-3036-501-RC-96-001, Hughes STX Corp., Lanham, MD, 1996.

Cebula, R. P., G. O. Thuillier, M. E. VanHoosier, E. Hilsenrath, M. Herse, G. E. Brueckner, and P. C. Simon, Observation of the Solar Irradiance in the 200-350 nm Interval during the ATLAS-1 Mission: A Comparison Among Three Sets of Measurements - SSBUV, SOLSPEC, and SUSIM, *Geophys. Res. Lett.*, in press, 1996.

DeLand, M. T., R. P. Cebula, and E. Hilsenrath, Solar UV Contributions to Stratospheric Ozone Variations 1989-1994, *XVIII Quadrennial Ozone Symposium*, submitted, 1996.

Hilsenrath, E., R. P. Cebula, M. C. Bories, J. J. Cerullo, P. W. DeCamp, L.-K. Huang, C. N. Hui, S. J. Janz, T. J. Kelly, K. R. McCullough, J. J. Mederios, J. T. Riley, B. K. Rice, and C. D. Thorpe, Contributions of the SSBUV Experiment to Long-Term Ozone Monitoring, *XVIII Quadrennial Ozone Symposium*, submitted, 1996.

Janz, S. J., E. Hilsenrath, R. P. Cebula, and T. J. Kelly, Observations of the Lunar Albedo during the ATLAS-3 Mission, *Geophys. Res. Lett.*, in press, 1996.

Woods, T. N., D. K. Prinz, J. London, G. J. Rottman, P. C. Crane, R. P. Cebula, E. Hilsenrath, G. E. Brueckner, M. D. Andrews, O. R. White, M. E. VanHoosier, L. E. Floyd, L. C. Herring, B. G. Knapp, C. K. Pankratz, and P. A. Reiser, Validation of the UARS and ATLAS Solar Ultraviolet Irradiances, *J. Geophys. Res.*, in press, 1996.

2.0 WORK PLANNED: 1 MARCH 1996 THROUGH 28 FEBRUARY 1997

During the upcoming period of performance, 1 March 1996 through 28 February 1997, efforts will concentrate on the development and analysis of the NOAA-11 SBUV/2 solar irradiance data set. First, the NOAA-11 SBUV/2 instrument characterization activity will be completed. Efforts to refine the characterization of the instrument's electronic calibration, amplifier gains, wavelength calibration, diffuser reflectance, and goniometric response are well underway and will be concluded in May 1996. In parallel to that activity, final SSBUV solar irradiances for the first seven SSBUV flights (October 1989 through November 1994) will be derived. Once the SBUV/2 internal characterization is complete and the final SSBUV solar irradiances are available, then the long-term calibration of the NOAA-11 SBUV/2 instrument will be determined via comparisons to the approximately yearly SSBUV flights. It is anticipated that this process will be completed in May 1996.

Analysis of the NOAA-11 SBUV/2 solar spectral irradiance data set will begin in earnest at that point. Time series at selected wavelengths will be developed and analyzed. The region near 205 nm, which is especially important for stratospheric chemistry, will receive particular attention. Also of special interest will be analysis of the data in the region near 230 to 250 nm, again due to the importance of this region for stratospheric chemistry and because time series from the two UARS instruments, SOLSTICE and SUSIM, show differences on the order of 3-4% during the declining portion of solar cycle 22. One or more papers discussing the analysis and findings will be submitted for publication, probably in the Journal of Geophysical Research.

Once the long-term NOAA-11 SBUV/2 characterization is finalized via the comparisons with SSBUV data, work will resume on developing the SBUV/2 composite Mg II proxy index based on discrete mode data. Although it is well established that measurements of the Mg II proxy index can be used to model the short-term behavior of the middle UV solar spectral irradiance, it is not yet proven that the Mg II index can be used to accurately predict long-term solar irradiance change in this spectral region. Long-term changes in the solar spectral irradiance measured by the NOAA-11 instrument will be compared with the variations predicted by the updated SBUV/2 Mg II index and scale factors.

We will continue working with NASA and NOAA personnel to acquire and analyze solar irradiance data from the NOAA-14 SBUV/2 instrument. Characterization of that instrument's long-term radiometric response will commence.

Solar spectral irradiances for the eighth and final SSBUV flight will be developed during this period. Analysis of the SSBUV data will be published in the Journal of Geophysical Research. As a follow-on to work discussed earlier, SSBUV data from the ATLAS-2 and ATLAS-3 missions will be compared to the coincident ATLAS SOLSPEC and SUSIM, and UARS SOLSTICE and SUSIM data sets. These comparisons will be published in the refereed literature.

We will continue to work with the GOME science team to validate the GOME solar spectral irradiances in the spectral region 240 to 406 nm. Assistance will also be given in refining and analyzing the GOME-based Mg II proxy index.

SOLERS22 will hold a workshop from 17-21 June 1996 at the National Solar Observatory at Sacramento Peak, Sunspot, New Mexico. As leader of WG 2 of SOLERS22, Dr. Cebula is a member of the scientific organizing committee for the SOLERS22 Workshop. In addition to presenting at least two and possibly three papers at the workshop, Dr. Cebula will assist in the selection and scheduling of oral and poster presentations. Dr. Cebula and Mr. DeLand will attended the Workshop, funded under the current research grant.

Dr. Cebula and Mr. DeLand will also participate in the XVIII Quadrennial Ozone Symposium, from 12-21 September in L'Aquila, Italy. Two papers related to this research have been submitted for presentation at the Symposium. Mr. DeLand's participation will be funded by this research grant; Dr. Cebula's travel to the Symposium will be supported via separate funding.

Figure 1

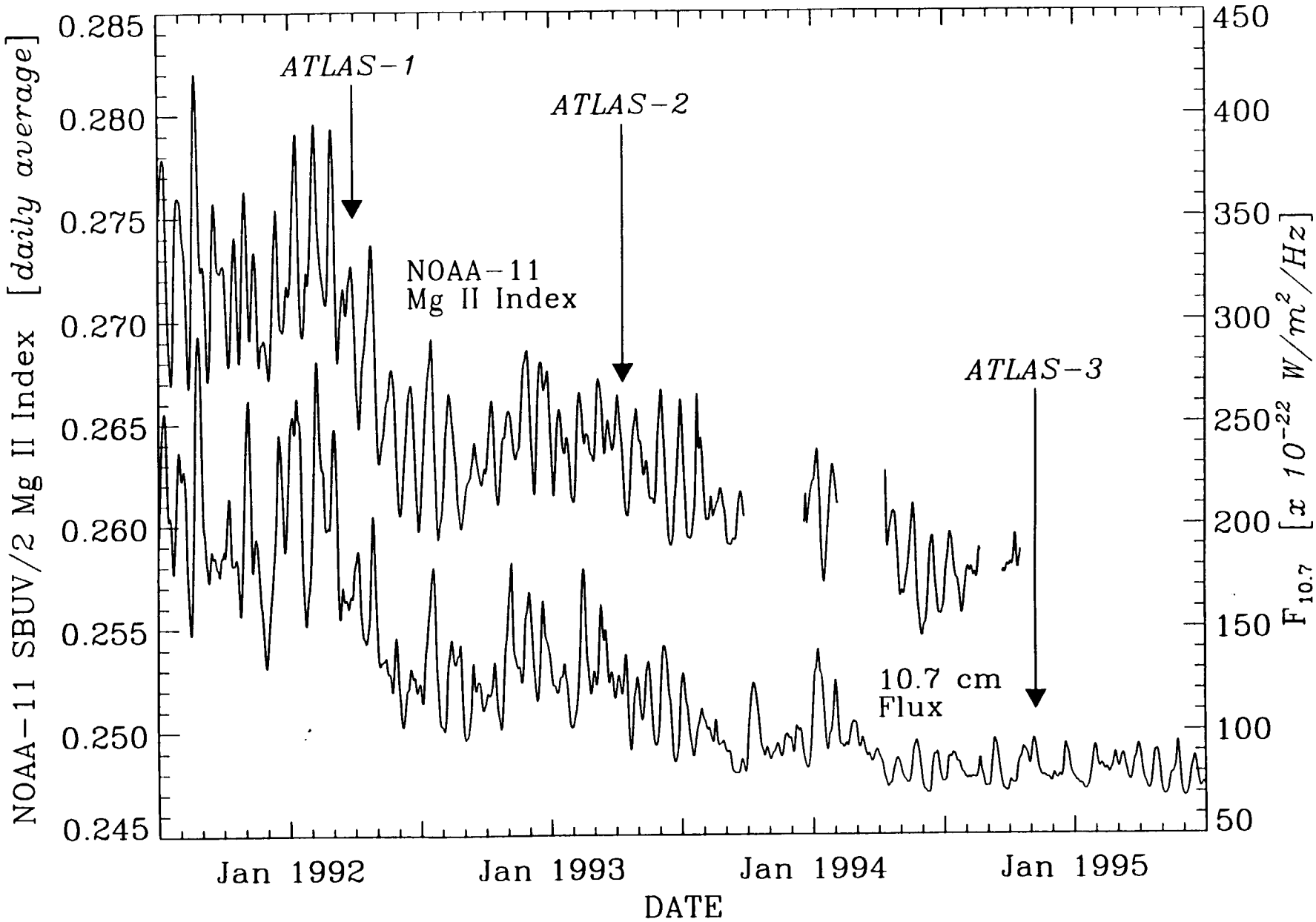

ATLAS-1
ATLAS-2
ATLAS-3
NOAA-11
Mg II Index
10.7 cm
Flux
NOAA-11 SBUV/2 Mg II Index [daily average]
$F_{10.7}$ [x 10^{-22} $W/m^2/Hz$]
0.285
0.280
0.275
0.270
0.265
0.260
0.255
0.250
0.245
450
400
350
300
250
200
150
100
50
Jan 1992
Jan 1993
Jan 1994
Jan 1995
DATE

Figure 2

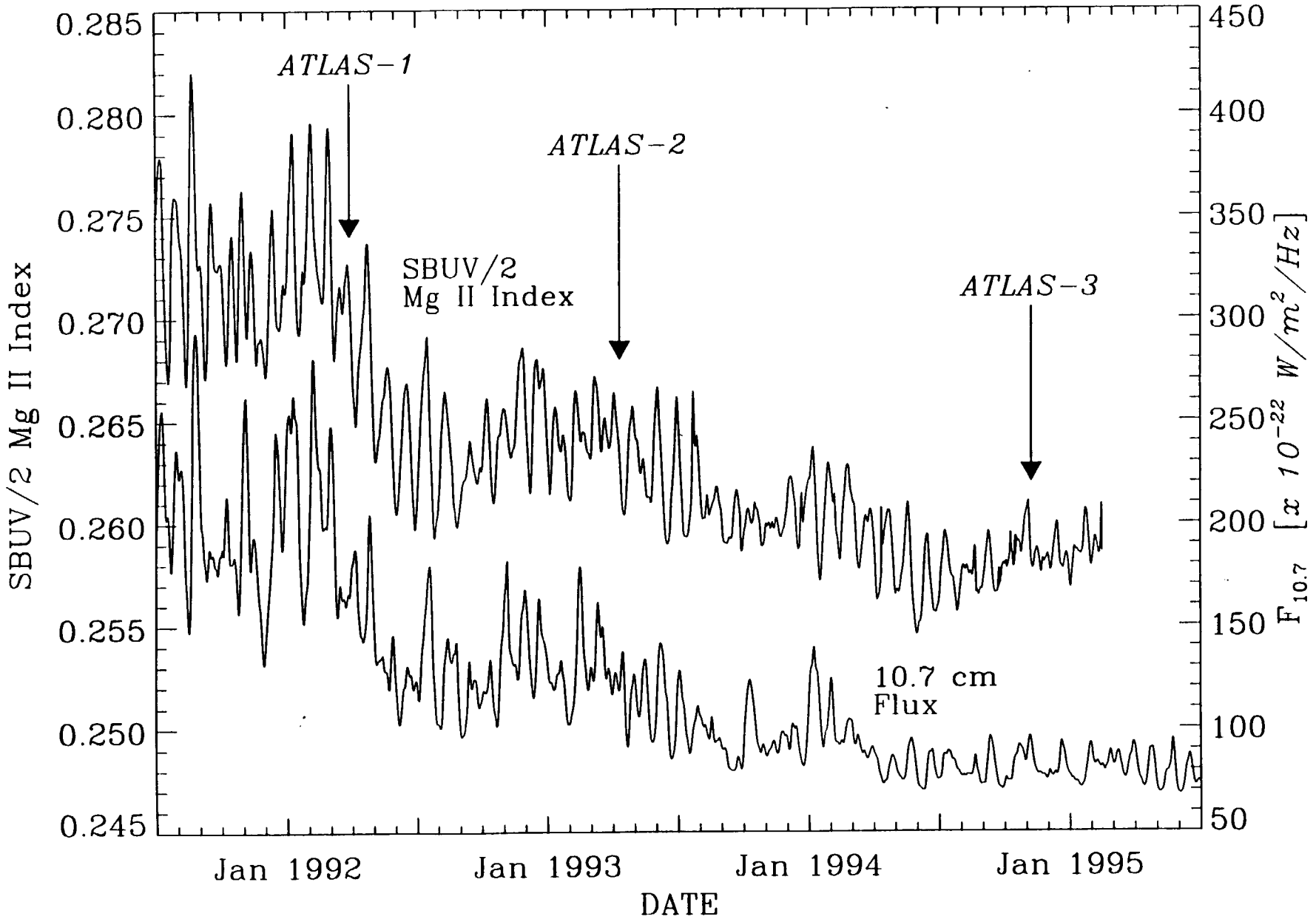
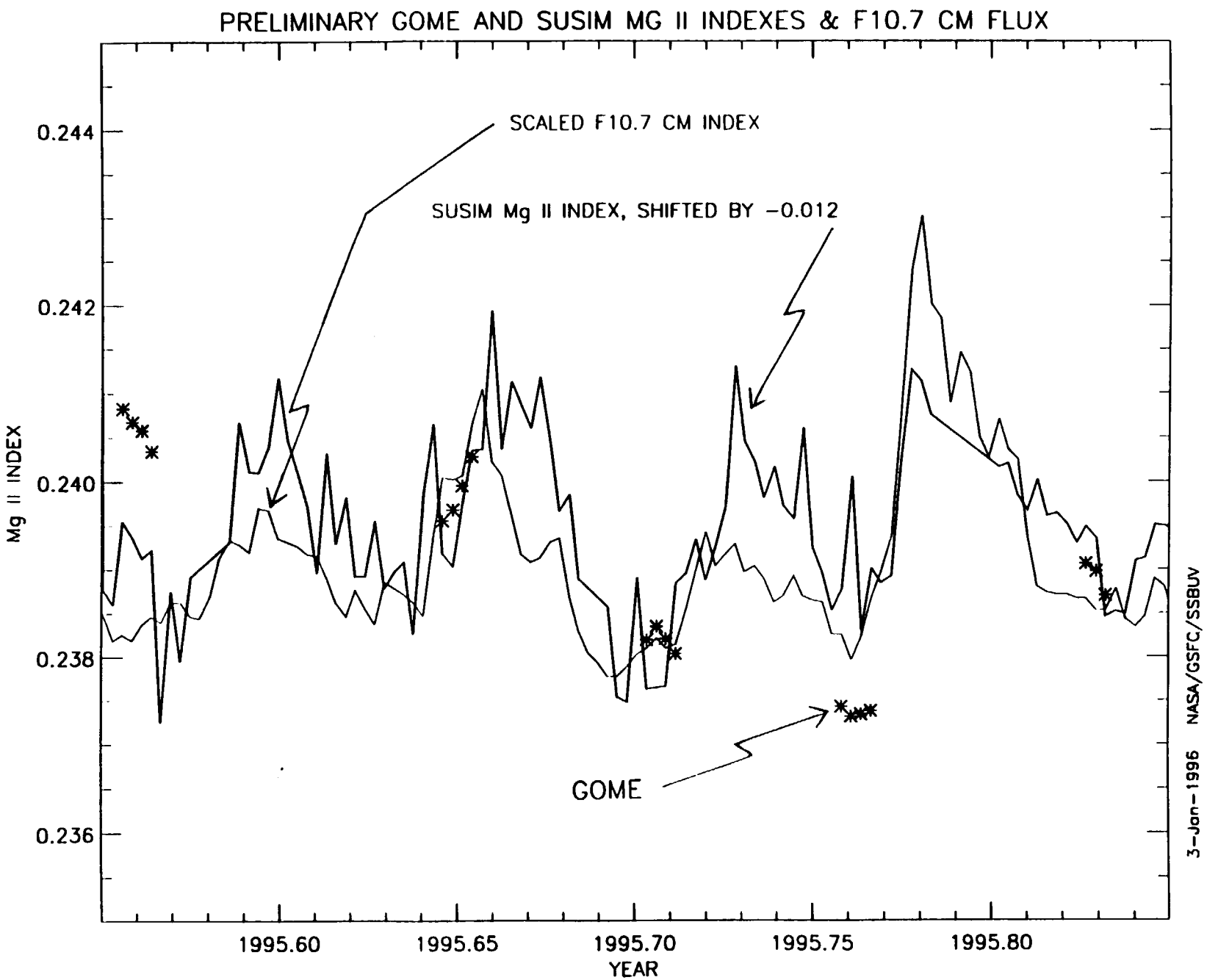

ATLAS-1
ATLAS-2
ATLAS-3
SBUV/2
Mg II Index
10.7 cm
Flux
SBUV/2 Mg II Index
$F_{10.7}$ [x 10^{-22} $W/m^2/Hz$]
0.285
0.280
0.275
0.270
0.265
0.260
0.255
0.250
0.245
450
400
350
300
250
200
150
100
50
Jan 1992
Jan 1993
Jan 1994
Jan 1995
DATE

Figure 3


PRELIMINARY GOME AND SUSIM MG II INDEXES & F10.7 CM FLUX
SCALED F10.7 CM INDEX
SUSIM Mg II INDEX, SHIFTED BY −0.012
GOME
Mg II INDEX
0.244
0.242
0.240
0.238
0.236
1995.60
1995.65
1995.70
1995.75
1995.80
YEAR
3-Jan-1996 NASA/GSFC/SSBUV